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ANALYSIS OF DATA AND EXAMINATION OF WORN PADS FROM TECOM T-142 TRACK PAD TEST

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ABSTRACT

Nineteen rubber compounds were tested in T142 tank track pads at the Yuma Proving Ground (TECOM Test 1-VC-087-142-027). The wear data were analyzed with the objective of selecting some of these compounds for use in a projected study of the correlation between field wear and wear on a test machine which is currently being constructed. Recommendations are made based on these data.

Some of the worn pads were sent to MTL and were examined visually and photographed. An abrasion pattern (i.e., a series of parallel ridges) was found on most of the pads which had been worn on the paved road course. Some of these patterns were examined in more detail by microscopy and profilometry. Some of the pads worn on the paved road developed long horizontal slits or pockets. On the hilly cross-country and combination courses, failure was primarily by chunking, though some pattern abrasion was also detected in a few pads.

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INTRODUCTION

In tanks and various other track-laying vehicles used by the U.S. Army, rubber pads are used to contact the ground. This is chiefly to minimize damage to roads, and also to provide vibration damping, noise reduction, and better traction under some terrain conditions. Tank track pads are subject to wear under extreme conditions of terrain, stress, and temperature (ambient and internally generated). Tank design emphasizes performance over durability, hence, the size and weight of the track components are held to a minimum, resulting in severe stress, heat buildup, and wear. Wear has been especially severe with the integrally molded T156 pads used on the M-1 tank and with the pads used on the Bradley Fighting Vehicle, but wear is also a significant problem with the detachable T142 pads used on the M-60 tank.

Since frequent replacement of tank track pads entails considerable expense to the Army, research and testing have been carried out for many years with the objective of increasing the useful life of these components.[1] One aspect of this research has been the development of improved rubber compounds, both by the Army (primarily at Belvoir Research, Development, and Engineering Center) and by commercial suppliers of tank track pads. Testing has been carried out by TECOM, primarily at the Yuma Proving Ground, Arizona (YPG), by actual field operation of a tank using tracks made up of strings of experimental pads together with a string of standard pads. Testing is performed on several courses at YPG, including a (nearly level) paved road, a hilly cross-country (HCC) course, and a level cross-country course. It is known[2] that wear on the HCC course involves extensive chunking, which may be caused by cut generation and growth, or may arise from internal heat generation and blow-out. Wear of T156 pads on the paved road was shown[3] to lead to the development of characteristic abrasion patterns; however, pattern development had not been reported[2] for T142 pads. Because wear proceeds by different mechanisms on the paved road and HCC courses, the durability of a given compound on one course is not necessarily related to its durability on another course. Thus, testing of research compounds is done preferably on individual courses; while for acceptance of commercial suppliers, a combination course is also used.

Field tests are expensive and time-consuming, and not highly precise. For these reasons, a test machine is currently being constructed by a contractor under the joint supervision of the U.S. Army Materials Technology Laboratory (MTL) and the Tank and Automotive Command, under the general heading of Project RESHAPE. In order to certify the applicability of this machine to the evaluation of tank track pads, it will be necessary to find machine operating conditions under which good correlation can be obtained between wear rates on the machine and actual field test results. This correlation testing will require sets of pads which cover a wide range of durability under the principal modes of wear.

The field test conducted by the U.S. Army Test and Evaluation Command under Project No. 1-VC-087-142-027 was a durability test of experimental rubber compounds molded in T142 tank track pads. The test was conducted at YPG using an M-60 tank. The tank was loaded to 104,400 pounds and run in three different test modes, as described in Table 1. Data were transmitted by F. B. Hoogterp of TACOM, 01 November 1989.

1. Elastomers and Rubber Technology. R. E. Singler and C. A. Byrne, eds., U.S. Government Printing Office, Washington, DC, 1987.
2. DWIGHT, D. W., and LAWRENCE, H. R. N. in Reference 1, p. 229.
3. MEDALIA, A. I., ALESI, A. L., MEAD, J. L., and SIMONEAU, R. *Pattern Abrasion as a Mechanism of Wear of Tank Track Pads on an Asphalt Road.* Paper No. 34 at a Meeting of the Rubber Division, American Chemical Society, Cincinnati, Ohio, October 1988.

Table 1. TEST CONDITIONS

Test Mode	Period	Speed (mph)	Maximum Duration (Miles)	Pad Weighing Interval (Miles)
Paved Road	Oct. '88 - Feb. '89	25 - 27*	3000	500
Hilly Cross-Country	Jan. '89 - Sept. '89	Variable†	500	At 100, 300 Then Every 300
Combination‡	Feb. '89 - Sept. '89	Variable	2500	500

*Maximum vehicle speed
†Maximum safe speeds
‡105 miles paved road, 225 gravel road, 135 level cross-country, 35 hilly cross-country cycle

Nineteen rubber compounds were tested, of which two were the same formulation but were mixed and molded by different producers. Not every compound was tested in all three modes. The compounds are identified in Table 2.

Table 2. TEST COMPOUNDS

Pad Group	Compound Number	Rubber Type	Manufacturer	Formulation Source
A	H	EPDM	G	V
B	Y	Carboxylated Nitrile	G	V
C	T	HNBR	G	V
D	NBR I6	HNBR	GD/P	B
E	15NAT-147A	NR	R	B
F	22SD700	–	GD	GD
G	15NAT-60	NR	R	B
H	NBR/NAT-150	HNBR/NR	GD	B
I	15NT12	NR/BR	R	B
J	15NP13	BR/NR	R	B
K	15NN7	HNBR/NR	R	B
L	698	–	L	L
M	K1A	NR/SBR/BR	R	B
N	K24	NR	R	B
O	NBR12	HNBR	M	B
P	K42	NR	R	B
Q	15NSP11	NR/SBR/BR	R	B
R	NSP4	NR/SBR/BR	R	B
S	Baseline	SBR	From Government Stocks 5/87 and 7/87	
T	NBR12	HNBR	F	B

N.B. HNBR used in Group D is from a different source than that used in other HNBR compounds

Our interest in these data is two-fold: (1) as a basis for selection of track pad compounds to be used for correlation testing of the tank track pad testing machine currently being constructed ; and (2) to characterize the type of wear experienced by pads of different materials and different wear rates under various conditions. The relations between the wear rate and the formulation and physical properties of the compounds would be of considerable interest, but we do not have the necessary information to investigate this.

SELECTION OF TRACK PAD COMPOUNDS FOR CORRELATION TESTING

Objectives

For establishment of a meaningful correlation between field test results and results obtained with a test machine, it is essential to use test samples (pads) which cover the widest possible range of wear rates. It is also desirable to include, at each level of wear rate, test samples of different composition and physical properties; this is because the test machine cannot duplicate field conditions exactly, so that the effect of certain properties on the wear rate may differ between the field and the machine. At this stage in the development of the test machine, it seems desirable to focus on development of correlations for wear under two single-mode conditions (paved road and hilly cross-country). Once such correlations (and the test machine conditions capable of giving good correlations) are established, it should be possible to devise a sequence of test machine conditions capable of giving good correlation with a mixed-mode test (combination course). This correlation would have to be confirmed, of course, with actual test results.

Analysis of Wear Data

Wear on the paved surface is a gradual process. It appeared that the most significant indicator of wear rate could be obtained by calculating the weight loss (grams) per 1000 miles when testing of that pad was terminated (i.e., when the pad was considered to have failed). Analysis of the paved road data is given in Appendix A. For each group of pads tested, the relevant data are given and the weight loss (at failure) and the loss per 1000 miles are calculated. Data from pads which failed prematurely due to problems with adhesion, backing plates, etc., are not included. The arithmetic average of miles at failure, and of the weight loss at failure, are also given. The average loss per 1000 miles is calculated in two ways: first, by dividing the average weight loss by the average miles; and second, by averaging the loss per 1000 miles of the individual pads. Comparison of these two results would give an indication of the scatter of the results.

On the HCC course, wear was generally by chunking, and was quite uneven across a pad (see EXAMINATION OF FAILED PADS). In view of the erratic nature of chunking, it appeared that the best indicator of wear rate on the HCC course was the miles-to-failure. The data are collected and averaged and shown in Appendix B. Data for miles-to-failure on the combination course are given in Appendix C.

There is some evidence that the wear of the pads at the beginning and end of a group of similar pads on the tank may be influenced by the wear of the adjacent pads of different composition and wear rate. An examination of the data was done in order to decide whether it might be preferable to omit from the data analysis the pads on the first and last shoe, or on the first two shoes and last two shoes, of a group of pads of the same composition. The examination did not show any consistent effect and, therefore, the data analysis given in this report was based on all pads (except those which failed for other reasons).

The data are summarized in Table 3. Pads A through I were tested on the left side of the tank and should be compared with the standard, S(Left), tested on this side; the remaining pads were tested on the right side and should be compared with S(Right). The average loss per 1000 miles was calculated by the second method described above. A lower loss value indicates superior performance, whereas a lower failed miles value indicates inferior performance.

Table 3. SUMMARY OF WEAR DATA

	Mean Wear Data				Wear Relative to Standard Pad			
	Paved Road		HCC	Combination	Paved Road		HCC	Combination
Group	Loss Per 1000 Miles	Miles-to-Failure	Miles-to-Failure	Miles-to-Failure	Loss Per 1000 Miles	Miles-to-Failure	Miles-to-Failure	Miles-to-Failure
S(Left)	399	1882	1105	2156	–	–	–	–
A	578	1316	1124	1918	1.45	0.70	1.02	0.89
B*	F	F	F	F	F	F	F	F
C	–	–	–	1281	–	–	–	0.59
D	263	2804	1617	1102	0.66	1.49	1.46	0.51
E	654	1119	1630	2221	1.64	0.59	1.48	1.03
F	441	1724	1126	1831	1.11	0.92	1.02	0.85
G	676	1311	–	1688	1.69	0.70	–	0.78
H	286	2717	844	1108	0.72	1.44	0.76	0.51
I	447	1612	729	1255	1.12	0.86	0.66	0.58
S(Right)	502	1563	1205	2063	–	–	–	–
J	899	740	1088	–	1.79	0.47	0.90	–
K	647	1094	1064	1656	1.29	0.70	0.88	0.80
L	522	1320	1492	2053	1.04	0.84	1.24	1.00
M	730	954	900	1813	1.45	0.61	0.75	0.88
N	345	2101	1137	2188	0.69	1.34	0.94	1.06
O	238	2909	1822	2594	0.47	1.86	1.51	1.26
P	864	823	987	1275	1.72	0.53	0.82	0.62
Q	834	846	–	1472	1.66	0.54	–	0.71
R	432	1879	–	1124	0.86	1.20	–	0.54
T	–	–	–	2389	–	–	–	1.16
					Statistical Analysis			
					A. Based on All Pads Tested in Each Mode			
				n	16	16	13	17
				$\bar{x}$	1.21	0.92	1.03	0.81
				σ	0.45	0.43	0.30	0.24
				$\sigma/\bar{x}$	0.37	0.46	0.29	0.30
					B. Based on Pads Which Were Tested in All Three Modes			
					Groups A, D, E, F, H, I, K, L, M, N, O, P. n = 12			
				$\bar{x}$	1.11	0.99	1.04	0.83
				σ	0.43	0.45	0.32	0.26
				$\sigma/\bar{x}$	0.39	0.46	0.31	0.30

*All pads of group B separated from the metal backing plate at low mileages indicated by F.

Table 3 also gives the mean wear of each group of pads relative to that of the standard pads, using left or right standard as appropriate. Only Compound O is better than the standard in all three wear modes. Several compounds (K, M, and P) are worse than the standard under all three conditions. Compound H is better than the standard on the paved road, but worse on the HCC and combination courses; the inferior wear on the combination course could be rationalized as due to a predominating effect of chunking (i.e., cross-country) type of wear on the combination course. However, Compound D appears anomalous in giving better wear than the standard on both the paved road and HCC courses, but much worse wear than the standard on the combination course. These results suggest that there may be some interaction of wear mechanisms which makes wear on the combination course more complex than simply an average of wear on the two single courses.

While the miles-to-failure (relative to the standard pad) covered a wide range (0.47 to 1.86), statistical analysis of the relative wear data shows that the mean performance of the pads tested is within approximately ±20% of that of the standard pads. Rather surprisingly, the standard deviation of the wear on the paved road is greater than on either the HCC or combination course. This is true regardless of whether the analysis is based on all pads

tested in a given mode or only on the 12 pad groups which were tested in all three modes. It must be stressed that this conclusion applies only to the particular set of pads tested in this field test. It would be of interest to examine previous field tests to see whether similar observations could be made.

The data can also be used to compare the performance of individual compounds in the three test modes (Table 4). Comparison of the miles-to-failure shows a wide variation between the three test modes. The average miles-to-failure relative to testing on the paved road course is 84% for the HCC course and 120% for the combination course. These values are in general accord with experience in that the HCC course is more severe (in spite of its lower average tank speed) than the paved road, while the combination course is less severe. However, some of the compounds did not follow this general pattern. Four of the 15 compounds gave longer miles-to-failure on the HCC than the paved road course; while five of the 17 compounds gave poorer miles-to-failure on the combination than the paved road course.

Table 4. COMPARISON OF MILES-TO-FAILURE ON DIFFERENT COURSES

Group	HCC/Paved	Combination/Paved
S(Left)	0.59	1.15
A	0.85	1.46
D	0.58	0.39
E	1.45	1.98
F	0.65	1.06
G	–	1.29
H	0.31	0.41
I	0.45	0.79
S(Right)	0.77	1.32
J	1.47	–
K	0.97	1.51
L	1.14	1.37
M	0.94	1.90
N	0.54	1.04
O	0.63	0.89
P	1.20	1.55
Q	–	1.73
R	–	0.60
		Statistical Analysis
	$n = 15$	17
	$\bar{x} = 0.84$	1.20
	$\sigma = 0.36$	0.48
	$\sigma/\bar{x} = 0.43$	0.40

Conclusions and Recommendations for Correlation Testing

For convenience in reviewing the wear data, the data have been summarized in Table 5, in which letter ratings are used. The number of pads which failed for other reasons is also given. Based on these results, the following conclusions and recommendations for selection of pads for correlation testing are made. Unfortunately, only a few groups of pads were prepared in sufficient quantity so that there are enough left over for correlation testing. Therefore, new pads will have to be procured and either field-tested or (less preferably) accepted on the basis of physical properties.

Table 5. LETTER RATINGS OF TESTED PADS

Comparison with standard pads tested on same side of tank: BB = much better than standard; B = better than standard; C = comparable to standard; W = worse than standard; WW = much worse than standard; F = failed for other reasons (adhesion, back plate, etc.); – = not tested. Comparisons of paved road data are based on average weight loss per 1000 miles at failure or at conclusion of test; comparisons of data on HCC and combination courses are based on averages of miles-to-failure.

	Comparison With Standard			
Group	Paved	HCC	Combination	Pads Available
A	W	C (2F)	C-W	2*
B	F	F	F	27
C	–	–	WW	9
D	B (2F)	BB	WW	0
E	WW	BB	C	2
F	C	C	W	0
G	WW (3F)	–	W	6
H	B	W (3F)	WW	0
I	C	WW	WW	2
J	W	C-W	-	20
K	W	C-W	W	2
L	C	B	C	2
M	W	W	C-W	3
N	B (1F)	C	C	2
O	BB	BB	B	0
P	WW	W	WW	2
Q	WW	–	W	1
R	B	–	WW	3
T	–	–	-B (7F)	32

*Only 2 pads were left of Group A-1. There are 25 pads left of Group A-2, with the same formulation but different mixing conditions; none of these were field-tested. There are 25 pads left of Group S from the same manufacturer.

1. Pads which are available are useful but not sufficient for establishing test conditions for correlation with field test data on **paved surface**. Group J is especially useful, since it is much worse than the standard.

2. Pads which are available are not useful for establishing test conditions for **hilly cross-country**, since they either gave results comparable to the standard or were not tested on this course.

3. Pads of which at least six are available may be useful and sufficient for correlation with the combination course since they include compounds which were worse (C and G) and somewhat better (T) than the standard. However, it is more difficult and more arbitrary to establish test conditions for a mixed mode, such as the combination course, than for relatively pure modes, such as the other two courses.

4. New pads should be prepared and field-tested, with ample extras for the test machine program, as follows: Groups H, I, and O, retest on paved surface and hilly cross-country. Group L, retest on hilly cross-country. This should give comparisons as follows:

Paved Surface		Hilly Cross-Country	
Group	Comparison	Group	Comparison
J	WW	I*	WW
A*, G	W	H*	W
I*, S*	C	A*, J, S*	C, C-W
H*	B	L*	B
O*	BB	O*	BB

*New pads

In addition, it would be desirable to fabricate and field-test pads of different design (larger or smaller area or thickness) of a compound, such as the triblend (MIL-T-11891-D), of which pads of standard design are also fabricated and tested in the same field test.

5. Group O uses a compound (NBR-12) with MPC carbon black. While this is not desirable for a production compound (in view of the high cost, overseas manufacture, and single-source availability of this material), for the present purpose this is the compound of choice since it has been thoroughly field-tested.

EXAMINATION OF FAILED PADS

Based on the wear data and field comments, several pads of each group were selected for examination. These included both typical and atypical pads of each group, amounting to a total of 107 pads out of 880 pads tested. These pads were sent to MTL from YPG. These include pads worn on the paved road (100 series), HCC (200 series), and combination course (300 series). Our visual observations of these pads, carried out with the naked eye and a low-power magnifying glass, are listed in Appendix D. Photographs and photomicrographs of some of these were made as described below.

Of greatest interest is the finding that wear on the paved road is generally characterized by the development of an abrasion pattern (i.e., a series of ridges running transversely to the direction of wear). A medium-coarse pattern can be seen in the photograph of the entire Pad L107 (Figure 1). To show greater detail, selected regions of three pads, as diagrammed in Figure 2, were photographed using a macro lens (Figures 3 through 5). The ridges run approximately parallel to one another but with some wandering and splitting. The spacing between ridges is clearly greater in Figure 3 (L107) than in Figure 4 (G105). However, it is difficult to obtain a precise estimate of the ridge spacing from examination of the photographs. Also, the photographs give no indication of the height of the ridges (or depth of the grooves). These aspects are discussed in detail in the next section.

Pattern abrasion, which is a well-known mechanism for wear of elastomers (especially on surfaces lacking sharp asperities), has been found previously on worn T156 pads[3] but has not been reported on T142 pads. This is because the conditions of wear are less severe with the T142 pads (lower load, lower speed), so that the pattern developed on standard pads is much finer (shallower, more closely spaced ridges) and could be overlooked. Among the pads we examined visually, it appeared that those exhibiting the lowest rate of wear gave the finest pattern, and in at least one case (Pad O111), no pattern was visible. A more definitive correlation between pattern development and rate of wear would require the examination of a number of pads by instrumental methods, as described in the next section.

The relation between pattern development and rate of wear is one of both cause and effect. Wear by a primary mechanism ("small-scale wear") leads to the development of ridges, which become organized into a pattern with fairly regular spacing. If the small-scale wear is slow, or has not proceeded far enough at the end of the test, an abrasion pattern is not developed. However, if the small-scale wear is sufficient to lead to pattern development, then the rate of wear is accelerated by the pattern itself.[4]

4. SCHALLAMACH, A. *J. Appl. Polymer Sci.* v. 12, 1968, p. 281.

Another interesting observation on the paved road pads is that the surface is generally concave, as shown by the fact that when the pad is placed on a flat surface, it rests on the outer and inner ends. Since the pad is actually manufactured to be convex, this indicates greater wear in the center than on the two ends. This must be due to passage of the road wheel over the center, with some flexing of the backing plate. In a few cases this flexing led to cracking or fracture of the backing plate.

Pad S110L developed a fine pattern near the leading edge, as shown in Figure 5. This pattern is too fine to be apparent in the overall photograph of this pad (Figure 6). In general, a fin is formed at the trailing edge (Figure 7), as shown previously on T156 pads.[3] This fin is eventually worn off, leaving a ragged edge and/or evidence of the removal of small chunks of rubber (Figure 6).

Some of the pads (such as the D, H, and R groups) developed long horizontal slits or pockets (Figure 8). Several of the pads appear to show a progression in the development of the slits or pockets. Pad D108 has two slits on its face: one, 1 inch long, 3/4 inch from the trailing edge, and the other, 2-1/2 inches long, 1 inch from the leading edge; and a 6 inch long slit on the trailing side, 1/4 inch from the face. A probe could be inserted from the 2-1/2 inch slit on the face to the 6 inch slit on the side. This showed that a large area, approximately in the center of the pad and 1/4 inch from the surface, had separated from the body of the pad nearly all the way from the leading edge to the trailing edge while still remaining joined to the body of the pad at the ends. This suggests that separation was due to internal evolution of gas (blowout), propagating through the hottest (weakest) zone of the rubber - a layer parallel to the face and apparently about 1/4 inch in from the present face. It is possible that blowout occurred more or less simultaneously along lines about 1-1/2 inch in from the leading and trailing edges, where temperatures have been calculated to be at a maximum.[5] Cutting the flap down the center showed that the area of separation covered nearly the entire area of the pad, similar to the area from which a flap had apparently come off (see Figures 9 and 10). Examination of the area of separation did not reveal any obvious signs of blowout, such as softened rubber, however. Pad D114 was basically similar to pad D108: it had a 4-1/2 inch slit on the face, 1 inch in from the leading edge, which communicated with a 3 inch slit on the trailing edge, 1/8 inch from the face.

Pad D308 had a large slit extending over about half the area of the pad, but not communicating with any other slit, probably indicating blowout which proceeded in one direction only. Pad R112 had a 5 inch long slit at the leading edge, and two smaller slits on the face, but none of these appeared to be in communication with the others.

On the HCC course, the observations made generally agree with those given in the field report (i.e., extensive chunking was found under these conditions of wear). Figure 11 (Pad N206) shows coarse, sharp chunking; while in Figure 12 (Pad J209), several regions of the pad appear to have been somewhat smoothed out. Removal of a flap, already shown in the H series on paved road, is illustrated for Pad H209 on the hilly cross-country course (Figure 13). It is remarkable that a few compounds (A and B) show some pattern development as well as chunking (by visual observation).

Only a few pads from the combination course were examined. These all showed extensive chunking (Figure 14), presumably occurring during the cross-country segments of this course. A pad which had been run on the combination course (P308) showed a pattern as well as chunking, not surprisingly since it had been run alternately under conditions conducive to both types of wear.

5. LESUER, D. R., GOLDBERG, A., and PATT, J. in Reference 1, p. 211.

DETAILED STUDY OF PATTERN ABRASION

Pattern abrasion has been studied previously by several methods including photomicrography, scanning electron micrography (SEM), and profilometry with a stylus instrument. Photomicrographs and SEMs of worn T156 tank track pads[3] have shown that, as known from previously published work on pattern abrasion of rubber compounds, the ridges which can be seen with the naked eye or a low-power lens are of a complex surface topography. At increasing magnification, smaller and shorter ridges are seen, and small tendrils and holes from these tendrils have been torn out. Some of these aspects are illustrated in a series of photomicrographs of Pad P114 (Figure 15). The appearance can be altered drastically by changing the direction of illumination (Figures 15A and 15B) or the angle of illumination (Figures 15E, 15F, and 15G). Comparison of the photographs taken from opposite directions demonstrates the "shingling" of the pattern, with the ridges digging into the direction of abrasion.

While the photomicrographs give a good qualitative impression of the patterns, they are difficult to characterize quantitatively. For this, we turn to profilometry. This method of surface analysis, widely used in the metals industry (ANSI/ASME B46.1-1985), is based on tracing the contour of the surface with a diamond-tipped stylus which moves in a straight line over the surface. Profilometry has been applied to worn rubber compounds by Stupak and Donovan,[6] who found that over a limited range the profile exhibits fractal geometry.

Profilometry of T142 pads was carried out with a Mitutoyo Surftest 401 and Analyzer 178-821. The stylus is mounted on an arm with a skid. The analyzer automatically plots the profile and calculates various parameters. Of these parameters, we have selected S_m and R_z (DIN), both measured in the filtered mode, to characterize the spacing and heights of the ridges, respectively. Some initial results are given in Figure 16 and Table 6. This work is on-going; a more detailed description of the procedure, and more complete results, will be given at a future time.

Table 6. PROFILOMETER RESULTS

Pad	Region Scanned*	Scanning Direction	S_m (μm)	R_z (DIN) (μm)	R_z (DIN)/S_m
P114	1	Toward Trailing Edge	758	115	0.152
P114	1	Toward Leading Edge	814	102	0.126
L107	1	Mean of Both Directions	759	84.5	0.111
G105	B	Toward Leading Edge	593	61.2	0.103
N102	1	Mean of Both Directions	716	43.1	0.060
S111R†	1	Toward Leading Edge	733	34.5	0.047
S111R†	2	Toward Leading Edge	635	35.5	0.056
S110L	1	Mean of Both Directions	587	36.5	0.062
S110L†	2	Toward Leading Edge	626	22.5	0.036
S110L†	3‡	Toward Leading Edge	516	26.4	0.051
S110L†	5‡	Toward Trailing Edge	579	22.4	0.039
S110L	6	Toward Leading Edge	683	33.1	0.048
I107	1	Toward Leading Edge	494	42.7	0.086
I107	2	Toward Leading Edge	489	46.8	0.096
I107	3	Toward Leading Edge	524	48.9	0.093
I107	5	Toward Leading Edge	515	44.4	0.086

*Regions are identified in Figure 2. Generally, scanning was carried out from the indicated spot in the direction given in the table. Repeat scans were made parallel to the first scan, typically at 0.25" on either side of it. When scanning was carried out in both directions, the second group of scans was carried out to the indicated spot.

†Little or no pattern discernible in the profilometer traces.

‡Single run on profilometer.

6. STUPAK, P. R., and DONOVAN, J. A. *J. Materials Sci.* v. 23, 1988, p. 2230.

The complexity of the profile is shown graphically in Figure 16. Note the different magnification of the X and Y axes. As shown in the table, the height of the peaks (mean of the greatest peak-to-valley height in each of five successive segments) is only a little over 10% of the peak spacing. Some regions in which no pattern was apparent to the eye, nevertheless, gave values for the parameters. Further study is underway to develop a method for determining the presence or absence of a pattern from the profilometer traces.

In Figures 16A and 16C, in which the stylus moved toward the leading edge, some of the peaks appear skewed to the right (i.e., the ridges bit into the road), as observed previously.[3] Conversely, in Figure 16B, with the opposite direction of stylus motion, some peaks are skewed toward the left. In general, however, most peaks observed in this study appear fairly symmetrical. In one case (Pad P114), a small difference was found between traces in opposite directions; in other cases, where only the mean is reported in Table 6, there did not appear to be any significant difference.

The profilometer data of Table 6 indicates a considerably greater variation in the heights of the ridges [(R_z (DIN)] than in their spacing (S_m). (This is, of course, only a tentative conclusion based on these very limited data.) The ratio of height-to-spacing varied from 0.036 to 0.152; the smaller ratios tended to be associated with the absence of a visible pattern or with a "fine" pattern. It is also of interest to note that there is less of a pattern in the leading and trailing edge regions of a standard pad (S110L) than in the end regions, despite the greater wear of the leading and trailing edge regions (shown by the concavity of the worn pad, described above).

SUMMARY AND CONCLUSIONS

This field test provided information from which it was possible to select groups of pad compounds exhibiting five levels of durability under each of two conditions of wear (paved road and hilly cross-country). Unfortunately, in most cases, the number of pads remaining after the field test is not sufficient to use for evaluation testing, therefore, it will be necessary to prepare new compounds and fabricate new pads.

Examination of the T142 pads worn on the paved road showed development of an abrasion pattern (a series of ridges running transversely to the direction of wear) on pads of virtually every formulation. By visual examination, it appeared that those exhibiting the lowest rates of wear gave the finest pattern. Initial data from profilometry measurements showed a much wider variation in height of the ridges than in the spacing between ridges.

Figure 1. Pad L107 (full view).

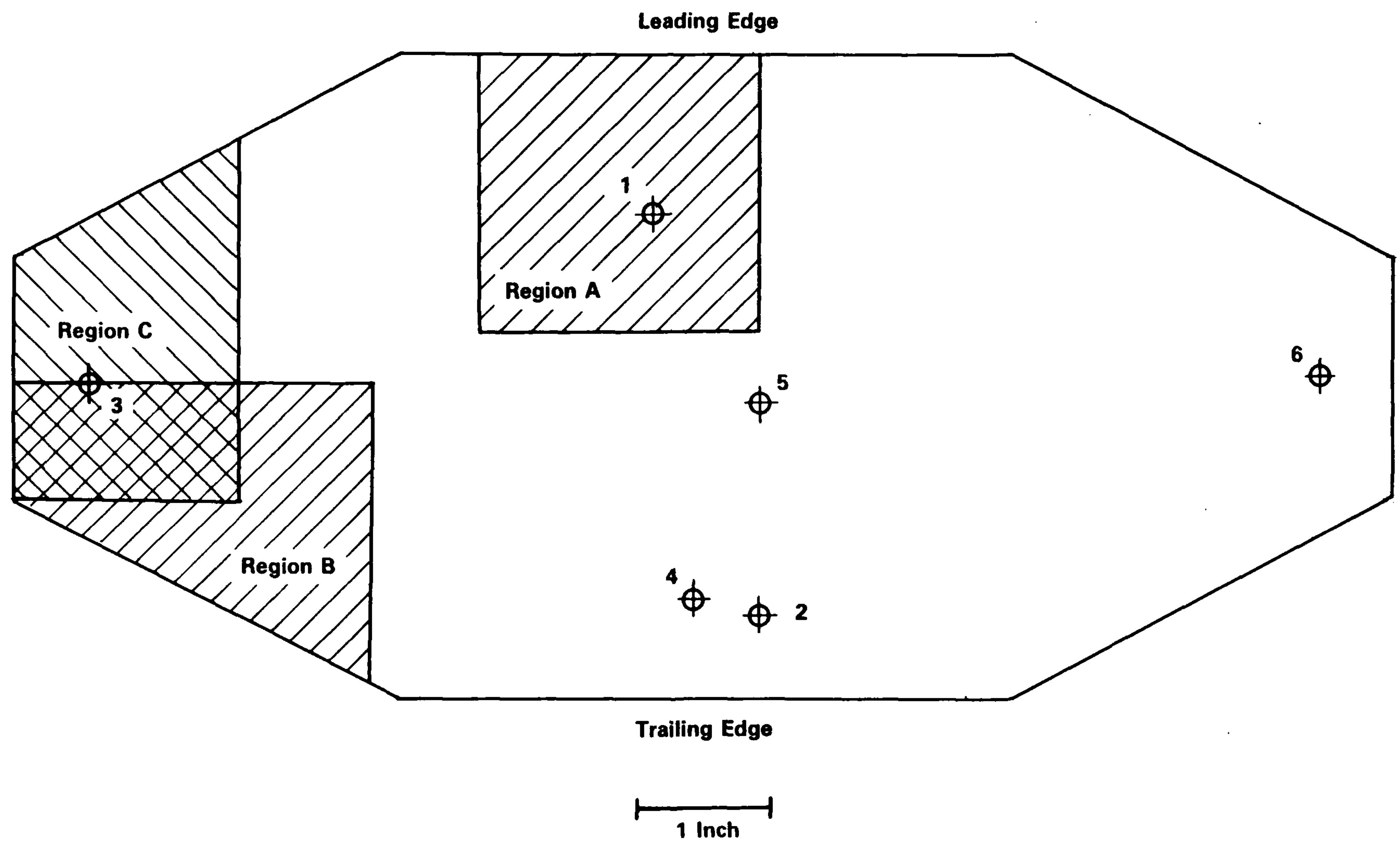


Figure 2. Diagram of pad face, indicating regions photographed in Figures 3 to 5, and spots marked for profilometer traces.

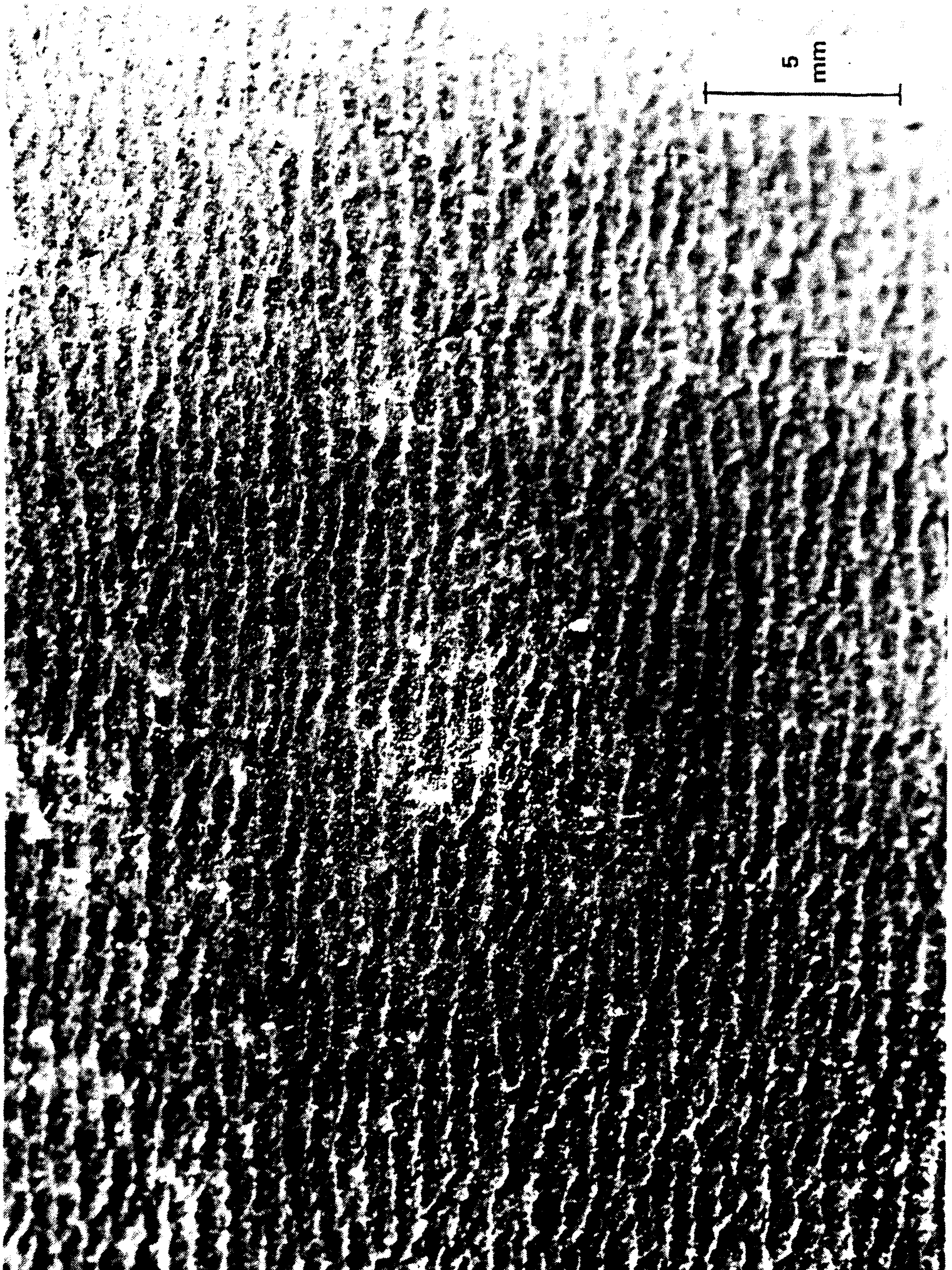


Figure 3. Pad L107 (enlargement of region A).

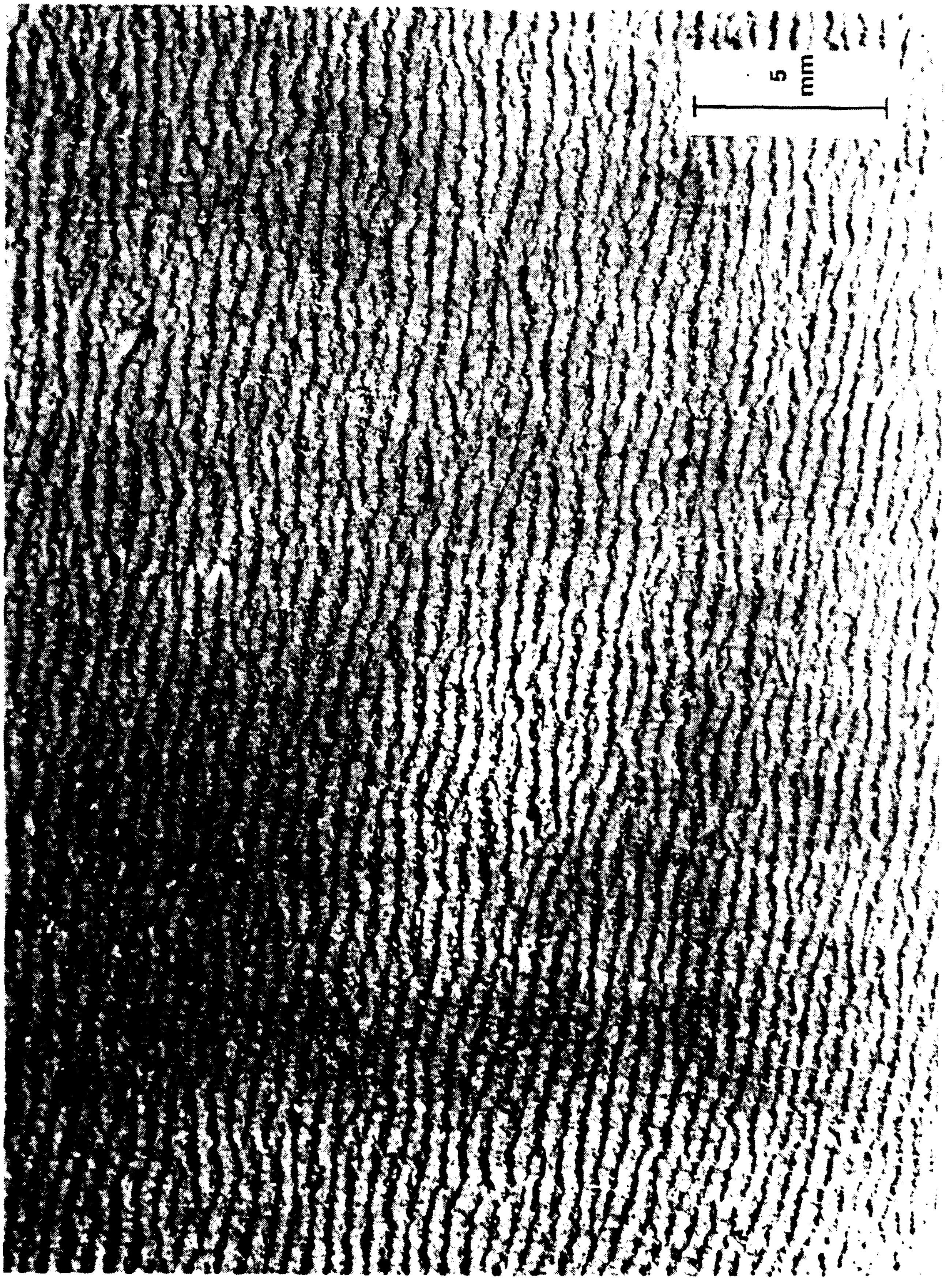


Figure 4. Pad G105 (enlargement of region B).

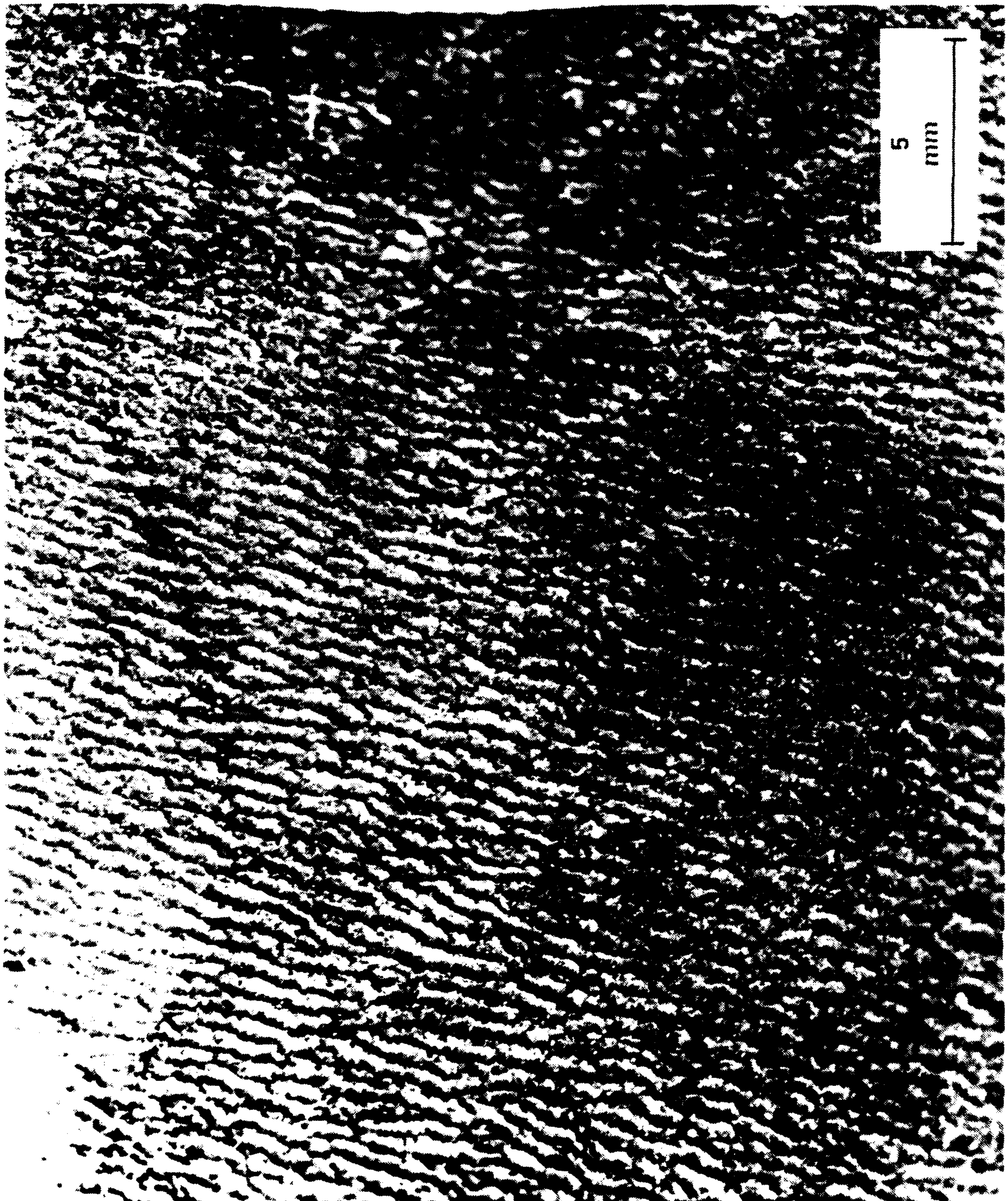


Figure 5. Pad S110L (enlargement of region C).

Figure 6. Pad S110L (full view).

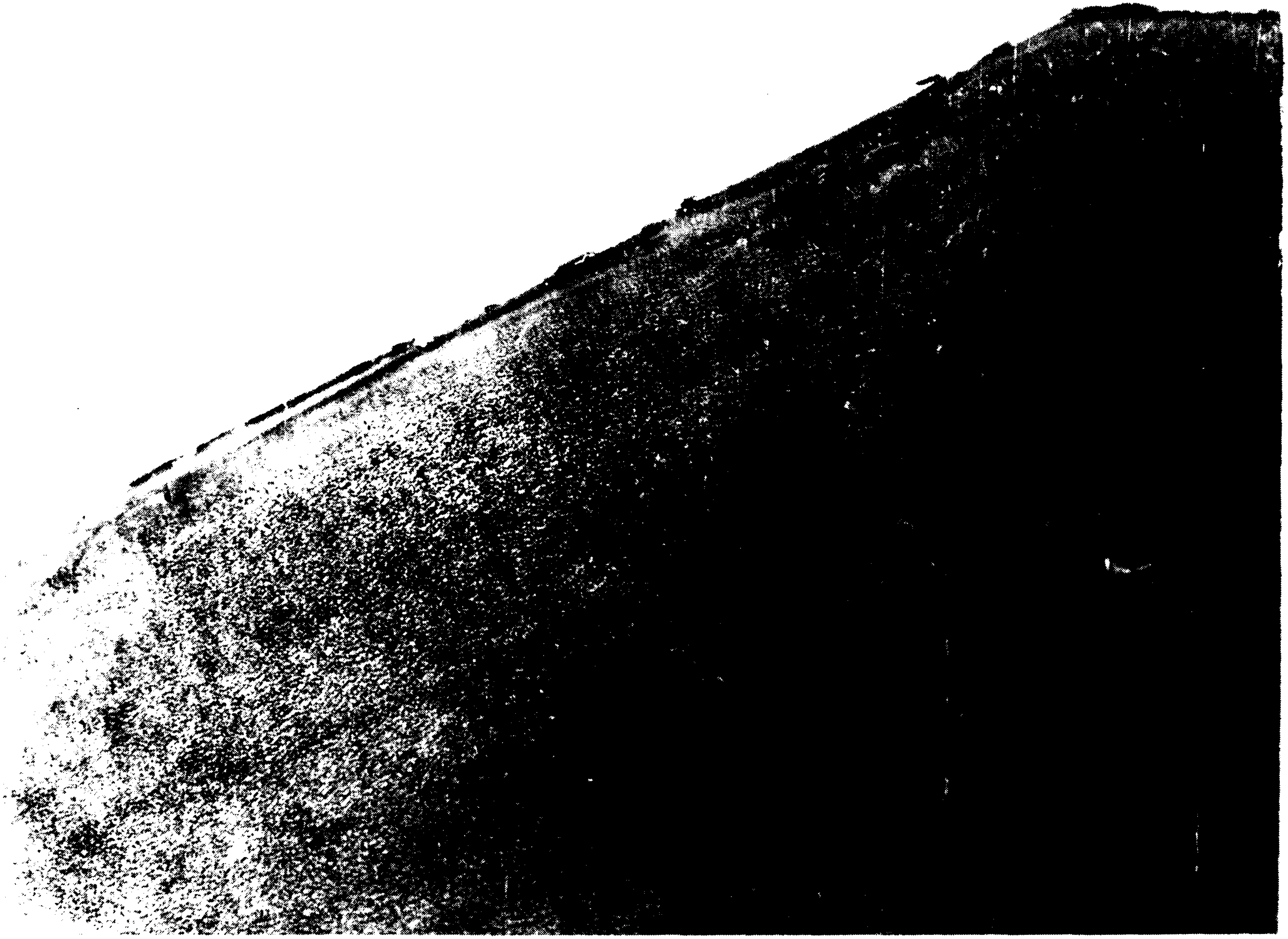


Figure 7. Pad A101, showing fin at trailing edge.

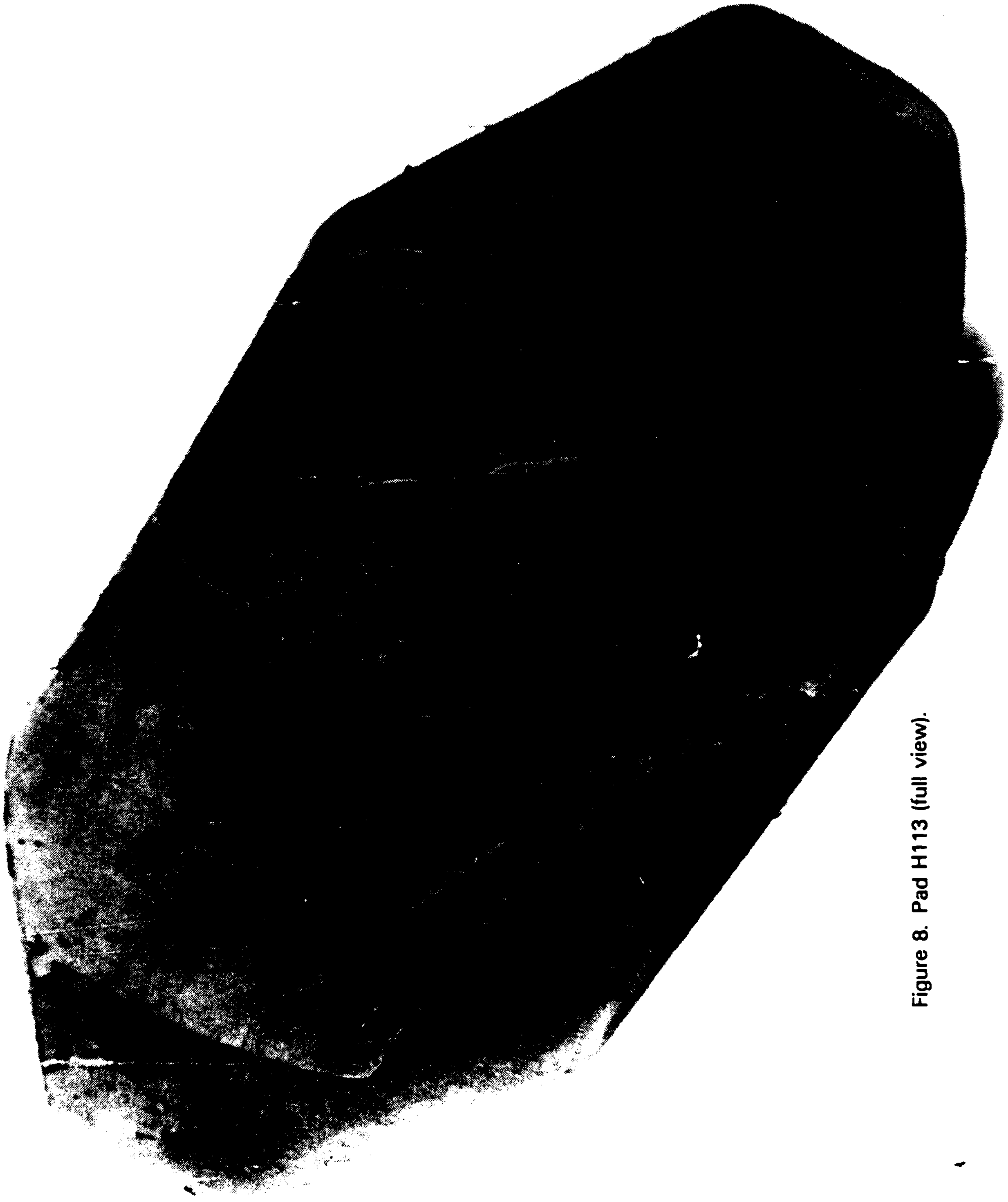


Figure 8. Pad H113 (full view).

Figure 9. Pad H115 (full view).

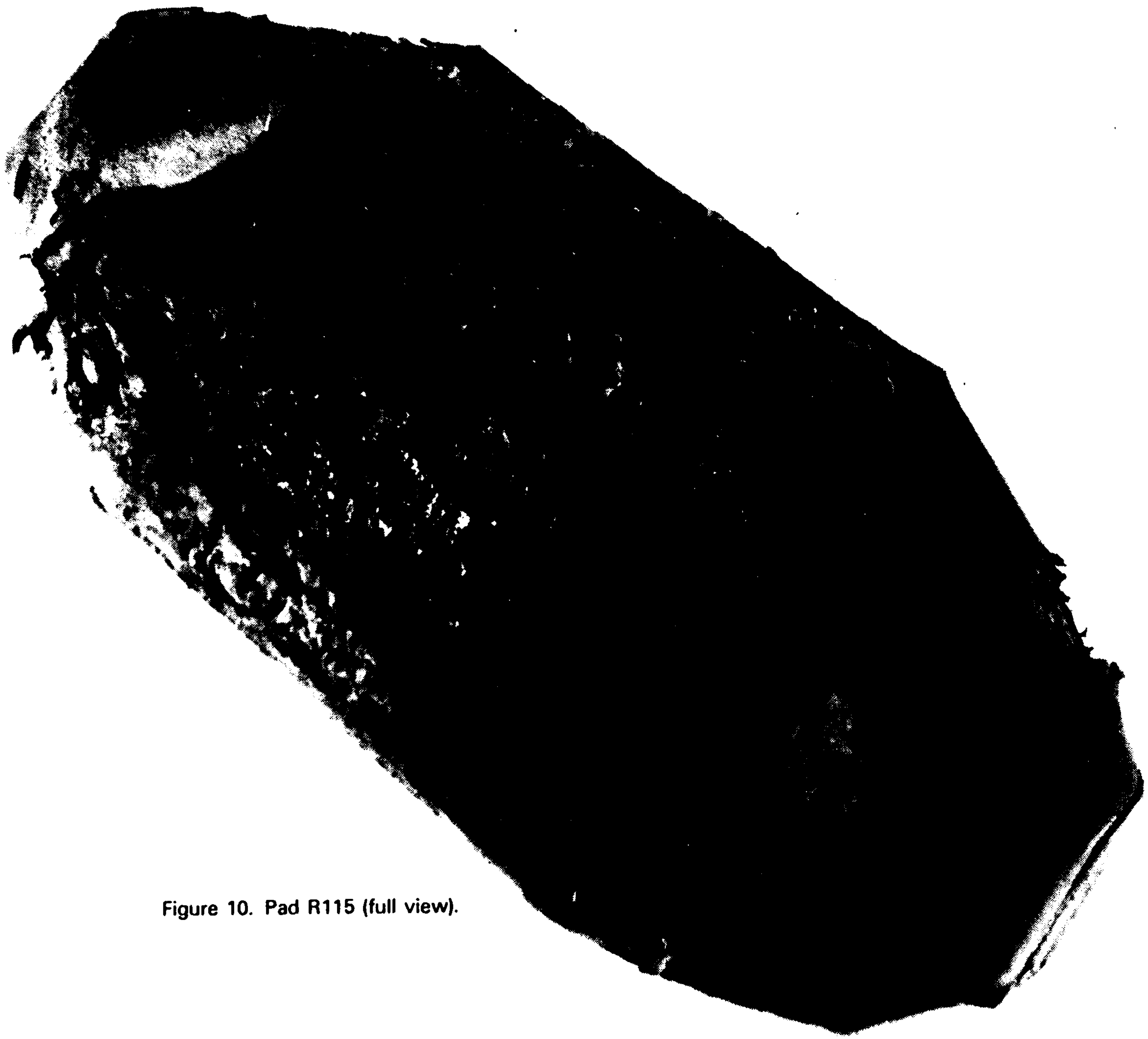


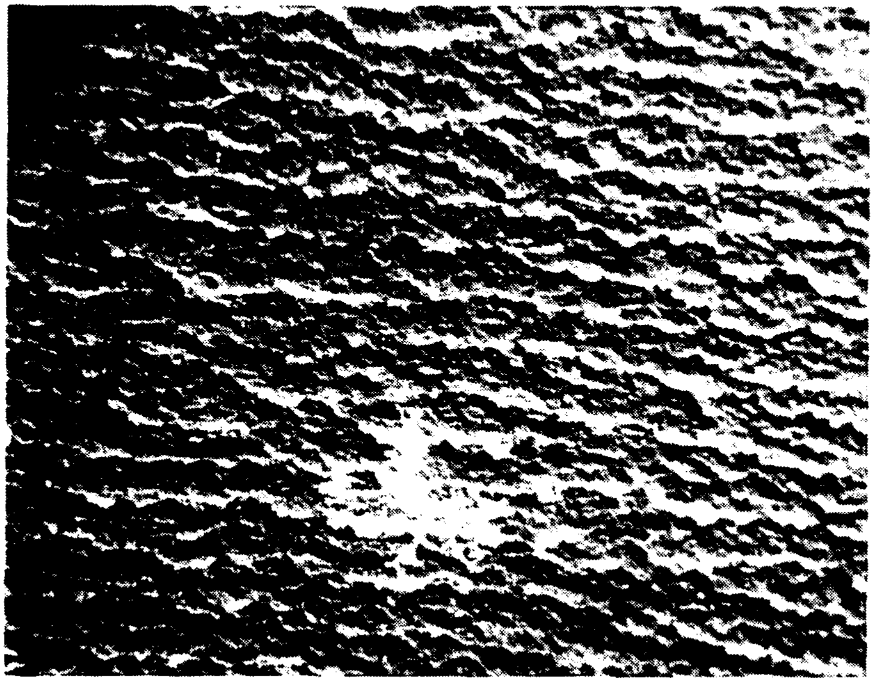
Figure 10. Pad R115 (full view).

Figure 11. Pad N206 (full view).

Figure 12. Pad J209 (full view).

Figure 13. Pad H209 (full view).

Figure 14. Pad C307 (full view).

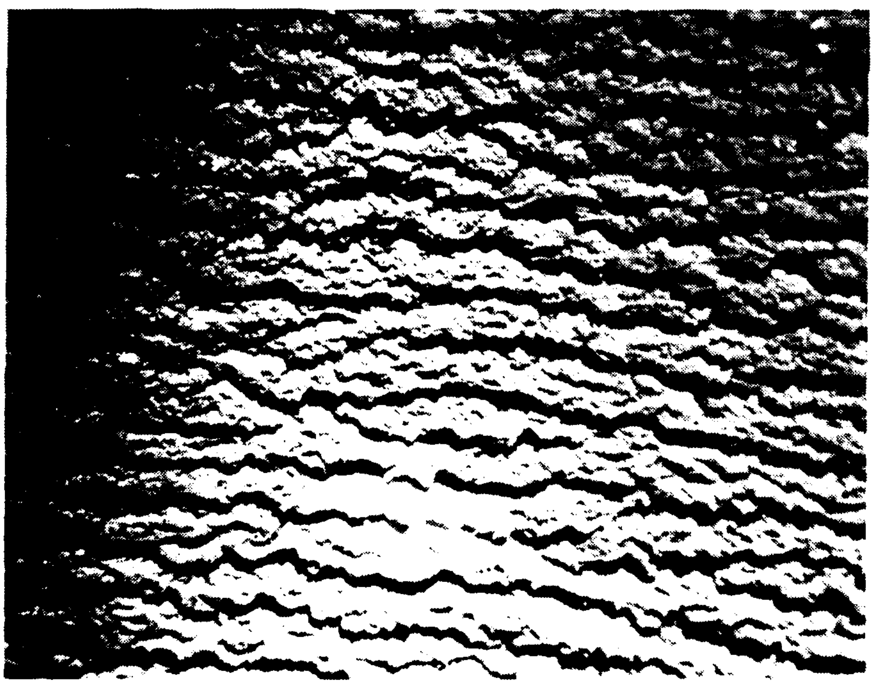


↑ Leading Edge

↓ Direction of Illumination

2 mm

A. Original at 7.8X, illuminated from leading edge at angle of approximately 20° from horizontal



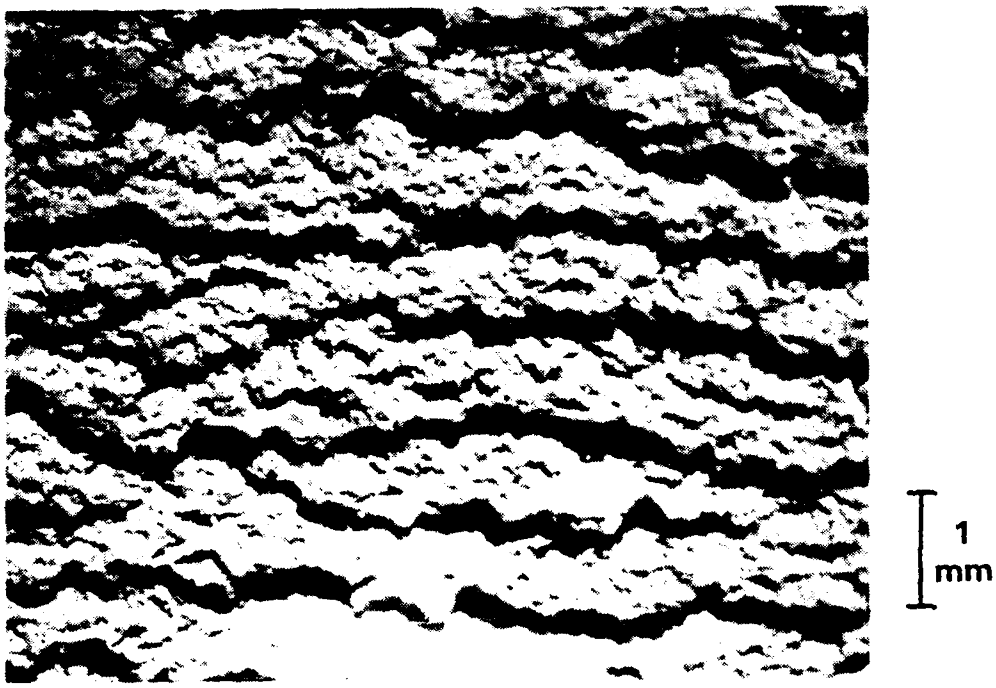
↑ Leading Edge

↑ Direction of Illumination

2 mm

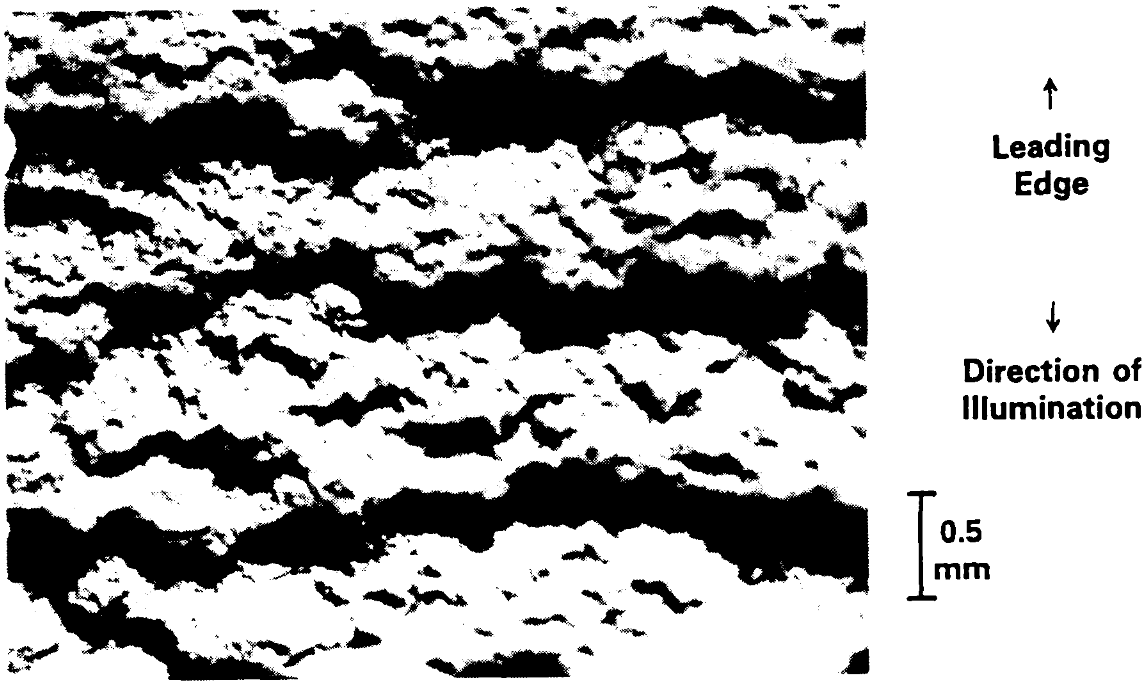
B. As (A), illuminated from trailing edge at angle of approximately 20° from horizontal

Figure 15. Photomicrographs of Pad P114, near leading edge. (Marker made with silver pencil at spot 1).

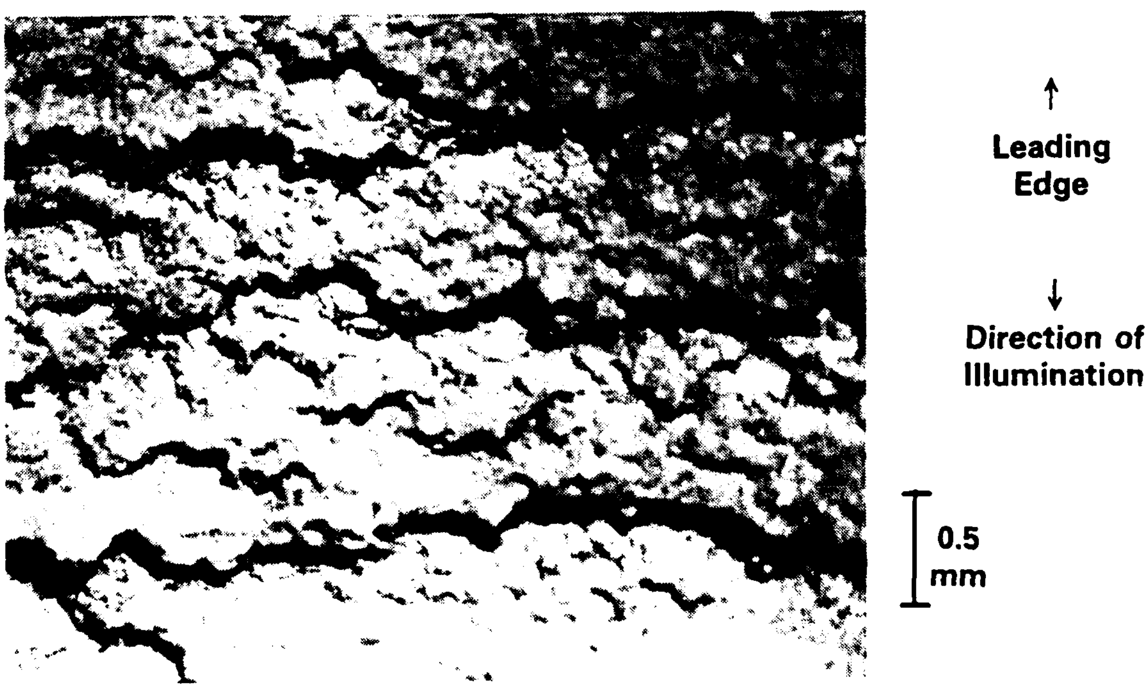


C. Original at 15.6X, illuminated as (B)

Figure 15 (continued).

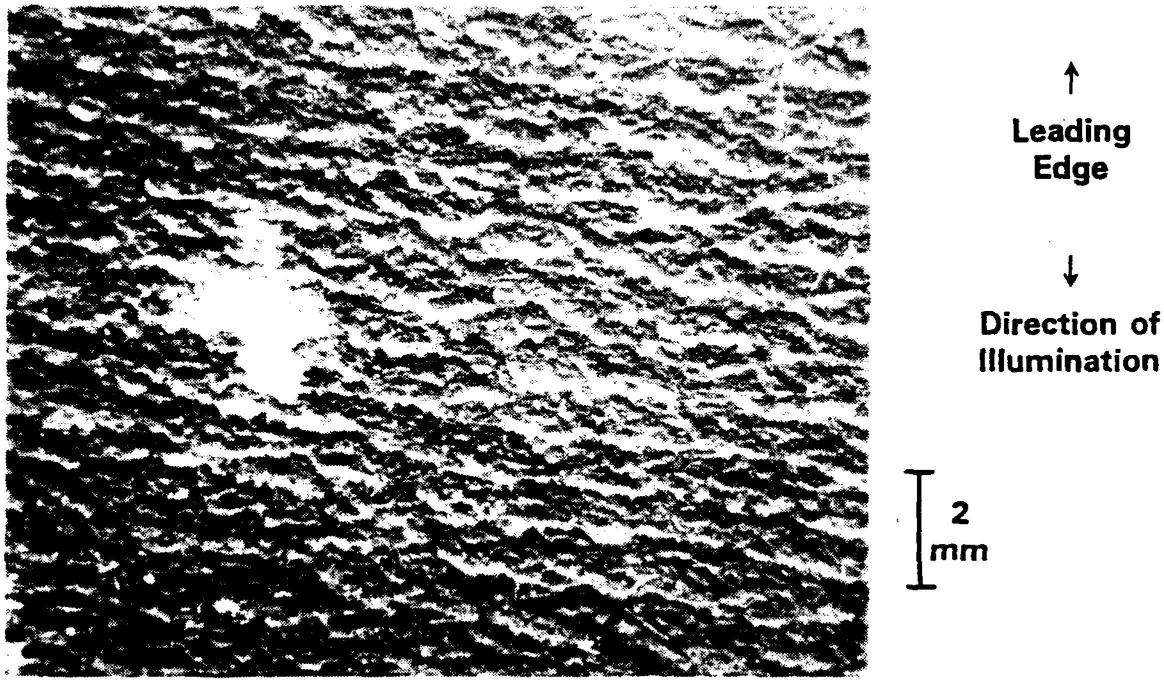


D. Original at 31.2X, illuminated as (B)

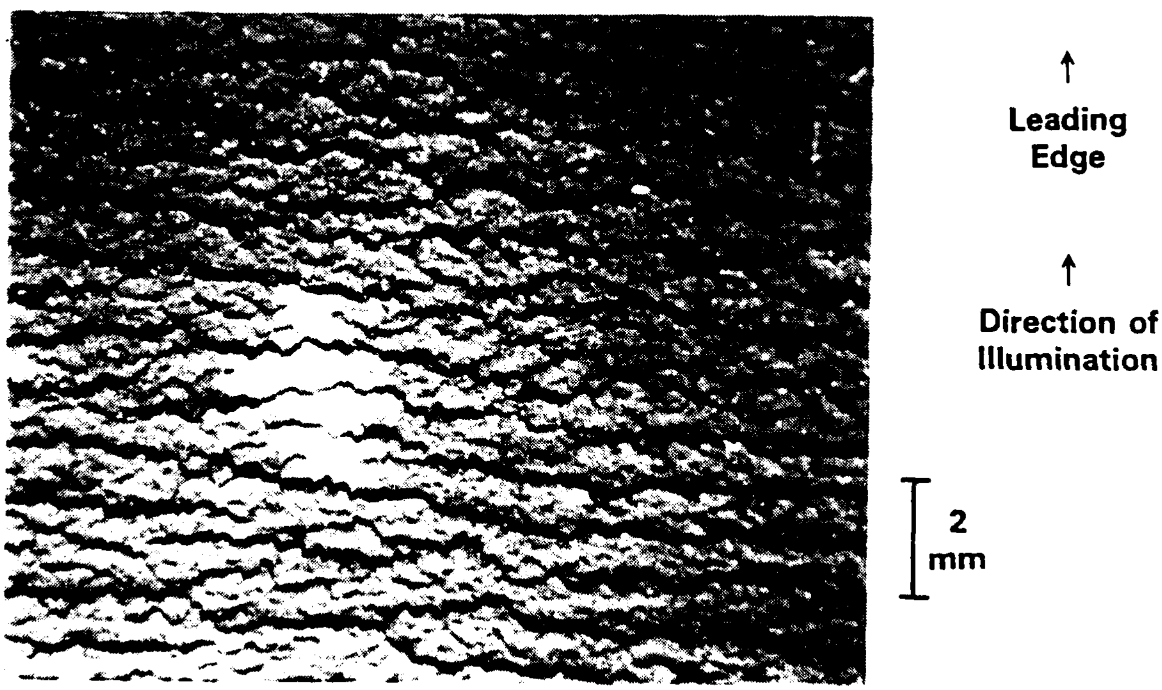


E. As (D), illuminated from trailing edge at angle of approximately 80° from horizontal

Figure 15 (continued).



F. Original at 7.8X, illuminated from leading edge at angle of 45°.



G. As (F), illuminated from trailing edge at angle of 45°.

Figure 15 (continued).

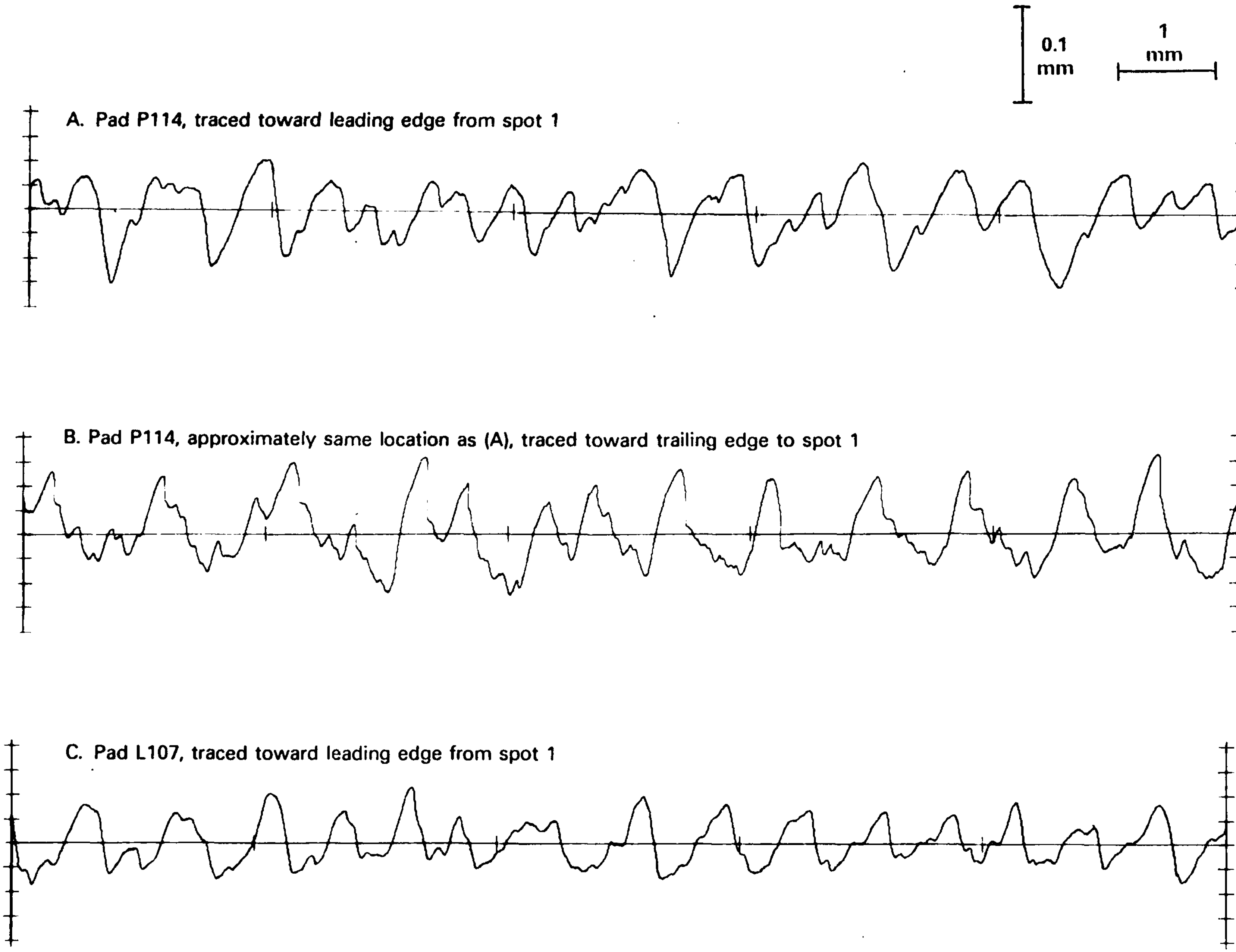


Figure 16. Profilometer traces. All traces made at same magnification.

APPENDIX A. WEIGHT LOSS AND MILES-TO-FAILURE - PAVED SURFACE

INITIAL WEIGHT	FAILED WEIGHT	FAILED MILES	WEIGHT LOSS	LOSS PER 1000 MILES	
	S-L				
2301	1511	1893	790	417	
2308	1604	1893	704	372	
2297	1529	1893	768	406	
2299	1571	1893	728	385	
2310	1525	1893	785	415	
2302	1564	1893	738	390	
2323	1550	1893	773	408	
2310	1594	1893	716	378	
2321	1535	1893	786	415	
2309	1558	1893	751	397	
2291	1540	1893	751	397	
2302	1582	1893	720	380	
2324	1575	1724	749	434	
2328	1568	1893	760	401	
2321	1572	1893	749	396	
2328	1595	1893	733	387	
	AVERAGE				
		1882	750	398	399
	A				
2238	1539	1254	699	557	
2248	1512	1254	736	587	
2238	1478	1254	760	606	
2240	1484	1254	756	603	
2246	1468	1254	778	620	
2255	1475	1254	780	622	
2244	1474	1254	770	614	
2253	1500	1254	753	600	
2258	1510	1254	748	596	
2248	1522	1254	726	579	
2241	1489	1254	752	600	
2234	1517	1254	717	572	
2247	1419	1500	828	552	
2247	1454	1500	793	529	
2239	1484	1500	755	503	
2252	1496	1500	756	504	
	AVERAGE				
		1316	757	575	578

D

2301	1548	2854	753	264	
2287	1533	3000	754	251	
2296	1541	3000	755	252	
2274	1575	3000	699	233	
2289	1581	3000	708	236	
2283	1633	3000	650	217	
2302	1562	3000	740	247	
2301	1577	3000	724	241	
2307	1555	2854	752	263	
2262	1566	3000	696	232	
2270	1530	2387	740	310	
2296	1537	2387	759	318	
2288	1540	2387	748	313	
2278	1540	2387	738	309	
AVERAGE					
		2804	730	260	263

E

2279	1634	809	645	797	
2273	1596	1141	677	593	
2268	1774	809	494	611	
2267	1533	1141	734	643	
2271	1564	809	707	874	
2270	1563	1141	707	620	
2276	1539	898	737	821	
2270	1493	1724	777	451	
2275	1598	898	677	754	
2273	1527	1724	746	433	
2278	1564	898	714	795	
2276	1578	1254	698	557	
2272	1599	898	673	749	
2279	1548	1254	731	583	
2276	1523	1254	753	600	
2280	1545	1254	735	586	
AVERAGE					
		1119	700	626	654

	F			
2301	1482	1724	819	475
2317	1507	1724	810	470
2315	1516	1724	799	463
2299	1535	1724	764	443
2316	1557	1724	759	440
2291	1544	1724	747	433
2309	1545	1724	764	443
2304	1567	1724	737	427
2301	1545	1724	756	439
2296	1578	1724	718	416
2297	1526	1724	771	447
2312	1580	1724	732	425
2306	1521	1724	785	455
2295	1549	1724	746	433
2272	1528	1724	744	432
2326	1623	1724	703	408

AVERAGE

		1724	760	441	441

H

2278	1514	2760	764	277	
2297	1553	2730	744	273	
2252	1522	2854	730	256	
2283	1537	2854	746	261	
2278	1570	2854	708	248	
2250	1575	2854	675	237	
2266	1522	3000	744	248	
2272	1591	3000	681	227	
2295	1560	3000	735	245	
2280	1619	3000	661	220	
2273	1568	2730	705	258	
2255	1572	3000	683	228	
2283	1606	2387	677	284	
2301	1570	3000	731	244	
2282	1351	1724	931	540	
2267	1348	1724	919	533	
AVERAGE					
		2717	740	272	286

I

2263	1557	1724	706	410	
2264	1561	1724	703	408	
2263	1573	1500	690	460	
2270	1590	1500	680	453	
2260	1517	1500	743	495	
2257	1543	1500	714	476	
2266	1527	1500	739	493	
2277	1554	1500	723	482	
2269	1518	1500	751	501	
2260	1574	1500	686	457	
2268	1531	1724	737	427	
2263	1552	1724	711	412	
2264	1525	1724	739	429	
2258	1537	1724	721	418	
2258	1533	1724	725	421	
2258	1544	1724	714	414	
AVERAGE					
		1612	718	445	447

S-R					
2311	1551	1398	760	544	
2313	1581	1398	732	524	
2318	1537	1398	781	559	
2306	1535	1398	771	552	
2326	1563	1398	763	546	
2326	1536	1724	790	458	
2322	1501	1724	821	476	
2395	1520	1724	875	508	
2321	1502	1724	819	475	
2305	1532	1724	773	448	
2314	1562	1500	752	501	
2302	1522	1893	780	412	
2313	1507	1500	806	537	
2318	1557	1500	761	507	
2316	1544	1500	772	515	
2300	1596	1500	704	469	
AVERAGE					
		1563	779	498	502

J					
2242	1624	675	618	916	
2238	1505	1071	733	684	
2230	1593	675	637	944	
2233	1633	675	600	889	
2245	1559	675	686	1016	
2249	1605	675	644	954	
2248	1577	675	671	774	
2236	1637	675	599	887	
2242	1565	675	677	1003	
2233	1597	675	636	942	
2231	1575	675	656	972	
2244	1610	675	634	939	
2242	1601	675	641	950	
2232	1624	675	608	901	
2237	1540	1000	697	697	
2236	1540	1000	696	696	
AVERAGE					
		740	652	881	899

K

2274	1518	1254	756	603
2277	1588	1254	689	549
2270	1584	1071	686	641
2273	1599	1071	674	629
2268	1560	1071	708	661
2268	1562	1071	706	659
2272	1560	1071	712	665
2262	1572	1071	690	644
2271	1577	1071	694	648
2255	1559	1071	696	650
2270	1589	1071	681	636
2275	1599	1071	676	631
2275	1549	1071	726	678
2270	1582	1071	688	642
2270	1500	1071	770	719
2272	1524	1071	748	698

AVFRAGE

L

2230	1579	1071	651	608	
2220	1635	1071	585	546	
2232	1529	1398	703	503	
2241	1595	1398	646	462	
2221	1555	1254	666	531	
2246	1548	1254	698	557	
2228	1531	1254	697	556	
2242	1527	1500	715	477	
2229	1534	1500	695	463	
2242	1483	1398	759	543	
2220	1480	1398	740	529	
2223	1542	1398	681	487	
2247	1571	1398			
2232	1512	1254			
2217	1557	1254			
AVERAGE					
		1320	686	520	522

M

2212	1525	898	687	765
2178	1529	898	649	723
2162	1420	898	742	826
2166	1447	898	719	801
2166	1463	898	703	783
2168	1476	898	692	771
2174	1501	898	673	749
2182	1536	898	646	719
2180	1531	898	649	723
2168	1539	898	629	700
2173	1499	1071	674	629
2175	1488	1071	687	641
2162	1452	1000	710	710
2220	1542	1000	678	678
2158	1473	1071		
2178	1521	1071		

AVERAGE

		954	681	714	730

N

2246	1567	2387	679	[illegible]
2245	1565	2387	680	285
2232	1508	2186	724	331
2287	1588	2186	699	320
2277	1555	2186	722	330
2270	1576	2186	714	327
2245	1522	2000	723	362
2236	1528	2000	708	354
2241	1529	2000	712	356
2255	1533	2000	722	361
2232	1479	2000	753	377
2231	1485	2000	746	373
2236	1489	2000	747	374
2236	1486	2000	750	375
2245	1505	2000	740	370

AVERAGE

		2101	721	343	345

O

2213	1468	2854	745	261	
2216	1499	2854	717	251	
2222	1496	2854	726	254	
2207	1505	2854	702	246	
2198	1500	2854	698	245	
2214	1533	2854	681	239	
2211	1499	2854	712	249	
2224	1564	2854	660	231	
2202	1502	2854	700	245	
2211	1556	2854	655	230	
2222	1548	3000	674	225	
2200	1547	3000	653	218	
2205	1508	3000	697	232	
2209	1539	3000	670	223	
2223	1519	3000	704	235	
2203	1539	3000	664	221	
AVERAGE					
		2909	691	238	238

P

2248	1602	694	646	931	
2206	1537	694	669	964	
2185	1545	694	640	922	
2192	1583	694	609	878	
2197	1493	694	704	1014	
2189	1533	694	656	945	
2236	1544	694	692	997	
2202	1522	694	680	980	
2196	1585	694	611	880	
[illegible]	1607	694	635	915	
				5	
				14	
				11	
				24	
				00	
				79	
				90	864

G

2451	1561	1141	890	780	
2358	1657	694	701	1010	
2305	1528	1000	777	777	
2446	1624	1000	822	822	
2262	1542	1141	720	631	
2447	1583	1141	864	757	
2373	1544	1000	829	829	
2318	1566	1141	752	659	
2337	1456	1500	881	587	
2228	1463	1893	765	404	
2349	1510	2085	839	402	
2444	1538	2000	906	453	
AVERAGE					
		1311	812	619	676

Q					
2207	1527	809	680	841	
2222	1544	1000	678	678	
2203	1515	694	688	991	
2193	1490	809	703	869	
2196	1518	694	678	977	
2250	1536	898	714	795	
2209	1472	898	737	821	
2278	1635	898	643	716	
2218	1400	898	818	911	
2246	1461	898	785	874	
2200	1528	898	672	748	
2193	1524	898	669	745	
2180	1516	809	664	821	
2204	1534	809	670	828	
2239	1541	809	698	863	
2220	1520	809	700	865	
AVERAGE					
		846	700	828	834

R					
2317	1512	1724	805	467	
2328	1556	2186	772	353	
2297	1518	2000	779	390	
2320	1525	2000	795	398	
2342	1540	2000	802	401	
2327	1562	2000	765	383	
2323	1516	2000	807	404	
2333	1538	2000	795	398	
2331	1545	2000	786	393	
2329	1534	2000	795	398	
2358	1536	2186	822	376	
2340	1533	2186	807	369	
2344	1649	1484	695	468	
2346	1544	1893	802	424	
2331	1593	1000	738	738	
2328	1563	1398	765	547	
AVERAGE					
		1879	783	417	432

APPENDIX B. MILES-TO-FAILURE - HILLY CROSS-COUNTRY

S (L)	A	D	E	F	H	I
1131	1200	1500	1697	1200	708	900
900	1076	1500	1714	1500	1098	900
1163	1076	1697	1697	1076	708	626
1200	1076	1714	1714	1076	1076	900
1076	1076	1500	1697	1076	708	626
1200	1076	1714	1714	1076	780	900
1076	1076	1500	1697	1076	780	626
1076	1076	1500	1714	1076	1076	626
1076	1076	1500	1697	1076	708	626
1200	1076	1714	1714	1076	1076	626
1076	1076	1500	1697	1076	708	626
1200	1076	1714	1714	1200	843	626
1076	1200	1697	1200	1076	708	626
1076	1500	1714	1714	1200		626
1076		1697	1200	1076		900
1076		1714	1500	1076		900
AVERAGE						
1105	1124	1617	1630	1126	844	729

S(R)	J	K	L	M	N	O	P
1200	900	1200	1200	900	1200	1800	900
1200	1200	1200	900	900	1697	1825	1200
900	900	900	1697	900	1200	1825	900
1200	1200	1163	900	900	1200	1825	900
1200	900	900	1200	900	900	1825	900
1200	1200	1200	1697	900	1200	1825	900
900	1076	900	1697	900	900	1825	900
1697	1200	1200	1697	900	1200	1825	900
1076	900	900	1697	900	1500	1825	900
1697	1200	1163	1697	900	900	1825	900
1076	1076	900	1500	900	900	1825	900
1200	1200	1200	1697	900	900	1825	900
1163	900	900	1697	900	900	1825	900
1200	1200	1200	1697	900	1200	1825	900
1163	1163	900	1200	900	900	1800	1200
1200	1200	1200	1697	900	1500	1825	1697
AVERAGE							
1205	1088	1064	1492	900	1137	1822	987

APPENDIX C. MILES-TO-FAILURE - COMBINATION COURSE

S (L)	A	C	D	E	F	G	H	I
2000	1500	1500	1087	2000	1500	1500	1406	1000
2500	1500	1500	1087	2500	2005	1500	1118	1500
2000	2000	1000	1087	2000	1500	1500	1087	1000
2500	1500	1500	1087	2500	2265	2000	1118	1500
1500	2000	1000	1000	2000	1500	1500	691	1000
2000	2000	1500	1087	2500	2265	2000	691	1500
2000	2000	1000	1000	2000	1500	1500	1000	1000
2000	2265	1500	1087	2500	2265	1500	1000	1500
2000	2500	1000	1087	2000	2000	1500	1609	1000
2500		1500	1087	2500	2000	2000	691	1500
2000		1000	1087	2000	1500	1500	2000	1000
2500		1500	1087	2500	2000	1500	1406	1500
2000		1000	1087	2000	1500	2000	1609	1000
2500		1500	1087	2265	2000	1500	500	1500
2000		1000	1087	2000	1500	2000	691	1087
2500		1500	1500	2265	2000	2000		1500
	AVERAGE							
2156	1918	1281	1102	2221	1831	1688	1108	1255

S (R)	K	L	M	N	O	P	Q	R	T
2000	2000	2000	2000	1500	2594	1500	1500	1049	2500
2000	2000	2000	2000	2000	2594	1500	1500	1049	2500
2000	1500	2060	2000	2000	2594	1500	1049	1049	2500
2000	1500	2060	2000	2000	2594	1500	1500	1049	2500
2000	1500	2060	2000	2000	2594	1049	1500	1049	2500
2500	2000	2060	2000	2000	2594	1049	1500	500	2500
2000	1500	2060	1500	2000	2594	1049	1500	1049	2500
2000	1500	2060	1500	2500	2594	1049	1500	1049	2000
2000	1500	2060	1500	2000	2594	1049	1500	1049	2000
2000	1500	2060	2000	2500	2594	1049	1500	1000	
2000	1500	2060	1500	2500	2594	1049	1500	1049	
2000	1500	2060	2000	2500	2594	1049	1500	1500	
2000	1500	2060	1500	2000	2594	1500	1500	1049	
2000	1500	2060	2000	2500	2594	1500	1500	1500	
2000	2000	2060	1500	2500	2594	1500	1500	1500	
2500	2000	2060	2000	2500	2594	1500	1500	1500	
2063	1656	2053	1813	2188	2594	1275	1472	1124	2389

APPENDIX D. DESCRIPTION OF TRACK SHOES SENT TO MTL AFTER TECOM TEST 1-VC-087-142-027

PAD ID	MILES-TO-FAILURE	DESCRIPTION
A101	1893	fine pattern; fin, short crack in plate.
A104	1254	medium pattern, slight fin.
A110	1254	medium pattern; slight fin.
A114	1500	medium pattern; rounded fin; or cracking approximately 1/4 inch from trailing edge.
A208	922	coarse pattern, poorly defined rounded surface high on horizontal center line; chunking around edges, 1 inch in; back plate has separated.
A209	1076	few pattern ridges in center; chunking all around edges, 2 inches wide.
A210	1424	same as A209.
B104	92	smooth, shallow pits 1/2 mm diameter mostly near edge, plate separated.
B106	118	same as B104
B108	77	same as B104
B109	29	same as B104
B114	59	same as B104 but pits slightly larger.
B201	415	very very coarse pattern, 3 mm, in center; extensive chunking within 1 inch of edge; plate separated.
B204	203	coarse roughness; one chunk, few cracks; plate separated.
B212	122	random cuts; small chunking plate separated.
B302	75	very smooth; same as B104.
B308	48	same as B302.
B310	33	same as B302.
B311	20	same as B302.
C307	1000	extensive chunking.
C308	1500	extensive chunking.
C309	1000	extensive chunking.
C310	1500	extensive chunking.
D108	3000	smooth, 7 inch wide, deep pocket starting from trailing edge, 1/2 inch below plate, 1/4 inch below surface; deep cut opposite pocket.

PAD ID	MILES—TO—FAILURE	DESCRIPTION
D109	2854	2 inch by 7 inch flap of pocket missing; slight pattern in spots.
D113	2080	most of bottom split off, 0-5/8 inch thick; piece recovered, has rough spots.
D114	1540	has pocket starting 1 inch from edge; rough spots; incipient pattern near ends.
D115	2105	same as D113.
D308	1087	large pocket; high ends; relatively smooth.
E104	1141	very fine pattern throughout; some pitting; slight fin; slightly more wear in center.
E108	898	same as E104.
E112	1254	same as E104.
F107	1724	looks like E104; fin torn off.
F208	1076	extensive chunking
F213	1076	extensive chunking.
F214	1200	extensive chunking.
G104	1000	medium pattern; slight chunking; several slits.
G105	593	medium pattern; deep striations near trailing edge; plate cracked at bolt.
G113	1500	very fine pattern.
G114	1893	medium pattern.
H113	2387	wide, 1-inch-plus deep, pocket; fine pattern 1/4 inch of trailing edge and at ends.
H114	3000	same as H113; very fine pattern overall.
H115	1724	pocket flap has gone, 7 inches wide by 3-1/2 inches; smooth surface over 1/2 near leading edge.
H208	780	7-1/2 inch by 3-1/2 inch pocket, flap gone; rough surface.
H209	1076	similar to H208 but worn to backing plate in two spots.
H210	708	missing.
I107	1500	medium pattern throughout; series of cracks near trailing edge; small chunks near one end and leading edge.
I204	900	extensive chunking.
I205	626	extensive chunking.

PAD ID	MILES-TO-FAILURE	DESCRIPTION
J108	675	medium pattern throughout; some pitting; fin.
J109	675	same as J108.
J114	675	same as J108.
J115	1000	same as J108; slight chunking near trailing edge.
J209	900	extensive chunking.
J210	1200	extensive chunking.
J211	1076	extensive chunking.
J212	1200	extensive chunking.
J213	900	extensive chunking.
J214	1200	extensive chunking.
J215	1163	extensive chunking.
J216	1200	extensive chunking.
K108	1071	fine pattern; series of cracks at 1/2 inch of trailing edge.
K207	900	extensive chunking.
K208	1200	extensive chunking.
K209	900	extensive chunking.
K210	1163	extensive chunking.
K212	1200	extensive chunking.
L107	1254	medium-coarse pattern; a few cuts.
L108	980	missing.
L109	1500	medium pattern; no cuts.
M108	898	missing.
M301	2000	incipient coarse pattern; extensive chunking 2 inches of edge; high ends and center.
M304	2000	same as M301.
M305	2000	same as M301.
M306	2000	same as M301.
M310	2000	same as M301.
M313	1500	same as M301.
N102	2387	medium-fine pattern thin fin.
N106	2186	fine pattern.
N107	2000	fine pattern.
N116	476	medium pattern; plate cracked; 1/2 of plate loose.
N206	900	extensive coarse chunking.
N207	900	same as N206.
N208	900	same as N206.

PAD ID	MILES—TO—FAILURE	DESCRIPTION
O110	2854	fine pattern.
O111	3000	no pattern.
P114	694	coarse pattern; coarse fin.
P115	1724	medium pattern; slight chipping near trailing edge.
P207	900	extensive chunking.
P308	1049	medium pattern in center; chunking around edge; some cuts.
Q102	1000	coarse pattern with chip near edge.
Q103	694	coarse pattern.
Q104	809	coarse pattern.
R112	2186	fine pattern; pits 5 inch split at trailing edge; cracks cuts or chunking 2 inches by 1/4 inch, 1 1/2 inches from trailing edge; plate cracked.
R113	1484	fine pattern; several cuts; cracked plate.
R114	1893	fine pattern; long cuts or pocket over leading edge; cracked plate.
R115	1000	fine pattern at ends; pocket flap missing, 6 inches by 4 1/2 inches; plate cracked.
S111R	1500	fine pattern.
S117R	1500	fine pattern.
S113R	1500	fine pattern.
S207R	900	large extensive chunking.
S208R	1697	same as S207R.
S209R	1076	same as S207R.
S210		same as S207R.
S211L	1076	same as S207R.
S110L	1893	fine pattern; tear at trailing edge.
S112L	1893	very fine pattern

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